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Drivers, Options and Approaches for Two Seaport Authorities on the Joint Reduction of Bunker Oil Related Emissions

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The international agreements, made by International Maritime Organization in 2008 are an encouraging start to reduce the SO_2 emissions caused by the use of bunker oil. Port authorities are confronted with a dilemma. From an environmental point of view, a proactive attitude is preferred. However, a unilateral initiative may jeopardize their bunker oil market share. In this article, we study the benefits and drawbacks of collaboration on emissions reduction between the ports of Rotterdam and Singapore. Many options for reducing SO_2 emissions and several policies strategies are discussed. Collaboration instead of competition may give a strategic financial advantage as compared to other would-be bunker harbors on the route Europe-Asia. Without a group of dedicated and critical actors, both port authorities do not have the power to enforce policies or options. The Rotterdam system can be regarded as a decentralized multi-actor network. The Singaporean situation may be characterized as a centralized authority. The process design towards cooperation should take into account these differences. Overall, it can be concluded that cooperation between the port authorities of Singapore and Rotterdam has extra benefits compared to a situation without cooperation.

Keywords: bunker cooperation emission reduction seaport sulphur

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Introduction

For quite a few years, limiting environmental damage due to air pollution has been an issue in political debates around the world. Regulations to decrease the amount of emissions have become stricter and stricter for the transport on land but relatively limited attention has been paid to the air pollution due to sea transport. However, neglecting this sea pollution may result in a significant increase of annual mortality rate (Corbett et al. 2007). The key pollutant is SO2 (sulphur dioxide gas), but the emissions also comprise NOx, heavy metals, particulate matter and CO2.

The SO2 emission on sea is caused by the sulphur content of the fuel that ships use. In the world of sea shipping, at this moment, bunker oil, a mixture of distillate oils and residual oils, is employed in marine engines (Donkers and Leemans, 2007). Distillate oils and residual oils are bottom products from processing crude oil in refineries and contain a wide pallet of heavy and complex components. Especially residual oil may have a relatively high sulphur content of several percent (Wilde et al., 2007).

Regulation for SO2 emissions is maturing: the current limits are determined and future limits will be more stringent (www.imo.org). When anticipating these developments Port authorities are confronted with a dilemma. From an environmental and legal point of view, a proactive attitude is preferred. However, a unilateral initiative may jeopardize their bunker oil market share. Cooperation could lead to a situation that is beneficial compared to individual approaches of emission reduction. Close collaboration between all seaports on the abatement of bunker oil related emissions would create a Worldwide Level Playing Field. In the current setting, however, this is a utopian dream.

The Port Authorities of Singapore and Rotterdam have comparable bunkering systems and are interested in understanding the mutual drivers, options and approaches in taking measures to reduce emissions due to bunker oil. To obtain a better understanding on the value of collaboration we will focus on collaboration between these two ports in the field of emission reduction. On other issues, these ports will remain competitors.

First, we look for the drivers for collaboration. The value of collaboration is determined by taking a closer look to the shipping route Singapore-Rotterdam. An analysis of regulations for SO2 emissions gives us insight in future trends. Next, we will make an inventory of options for emission reduction and option for policy measures, which may be applied to stimulate the emission reduction. As the port authorities of Singapore and Rotterdam are embedded within a complex social system, we will apply an actor analysis to enlighten the social structures. Finally, we will draw conclusions.

The value of collaboration

To determine the value of collaboration, we have to explore the position of the Port of Rotterdam and the Port of Singapore in more detail.

The shipping routes between Asia and Europe and in particular between the ports of Singapore and Rotterdam are busy routes. Most of the time, ships do not specifically sail between these two ports, but they call several ports in the region. E.g., the Asia – Europe Express of APL calls the following ports in the following order: Kwangyang - Pusan - Kaohsiung - Hong Kong - Singapore - Rotterdam - Hamburg – Thamesport [APL, 2008]. Ships may frequently change the ports of call. However, within the shipping route between Asia and Europe, the ports of Rotterdam and Singapore are the traditional refueling ports (see Table 1).

Table 1. Bunker sales in the ports of Rotterdam and Singapore in ktonnes per year

Year	Rotterdam	Singapore
2005	13145	25479
2006	13662	28379
2007	13581	31546

Bunker oil is made available in the Port of Rotterdam via two different ways: crude oil distillation and import. The crude oil in the port of Rotterdam comes from three different locations. About one third of the crude oil originates from the North Sea, one third originates from the Middle East and one third originates from Russia. This crude oil needs to be processed in order to become useful for fueling ships. The origin of the crude oil determines the quality of the oil that arrives in the port for a large part. The oil coming from Russia is for example of less quality that the oil from the Middle East. Despite this, the quality of crude oil can also differ within one origin. This means that some crude oil needs to go through longer and more extensive processes before it eventually reaches the right level of quality of bunker oil. The other way of getting fuel oil to the port is by importing fuel oil itself to Rotterdam. The crude oil has already been processed to fuel oil on another location. This means that it does not need to undergo processes other than possible blending before it is being used. Half of the fuel oil in the Netherlands is exported and a little less than half of the fuel oil is actually used as bunker (see Table 2).

Like Rotterdam, Singapore does not have its own oil reserves. Crude oil is imported from different places around the world and processed in large refineries in Singapore to a number of levels of quality. The constituents of bunker oil are mainly imported from places as Europe, the Middle East and South Korea (Sivanandam and Prodduturi, 2008). In Singapore, most of the constituents of bunker oil are imported and a large share, especially gas and diesel, is again exported. Still, a large share of these oils are used as bunker oil (see Table 2).

Table 2. Oil statistics 2005 of the ports of Rotterdam and Singapore in ktons per year (International Energy Agency, 2008)

	Gas/Diesel		Residual Fuel Oil	
	Rotterdam	Singapore	Rotterdam	Singapore
Production	21122	14474	12394	9798
Imports	9650	3860	22395	30414
Exports	-21061	-14679	-17069	-12036
International Marine Bunkers	-1934	-1546	-15350	-23933
Stock changes	-546	-786	-248	806
Domestic supply	-7231	-1323	-2122	-5049

Without collaboration, the ports of Singapore and Rotterdam are competitors in the bunker oil market. If bunker oil prices in the two ports differ too much, e.g. by a unilateral levy in the Port of Rotterdam, ships may consider to bunker only in one port for a round trip. Bunker oil traders may decide to rebalance their activities and shift the bunker oil trade to another port. These free market processes result in a competitive bunker oil market.

Collaboration between the Port of Rotterdam and the Port of Singapore will reduce the competitiveness of the market. However, collaboration will expand the window for implementing reduction options and policies. When Rotterdam and Singapore jointly decide to discourage the emission of SO2, other ports, like Fujairah, may become competitors. . Fujairah has already outgrown the Port of Rotterdam as a bunker port and is now number two of the world (Fujairah, 2009).

Figure 1 shows two different sailing routes between Singapore and Rotterdam. The short one, no. 1, uses the Suez Canal and the longer one, no.2, sails all the way around Africa. The first route is shorter in length but the Suez Canal limits the size of the vessels. Larger vessels will need to use the route rounding Africa.

The decision to change the shipping route by ship-owners is generally driven by economics. The deciding factors are the change in length of the shipping route, the bunker quality, the price of bunker, the amount of bunker needed, the type and the size of vessel, the amount of cargo, the time in port, pilotage, the equipment costs and other ports costs. For a reference ship, estimators were developed for the determination of the value of the different cost elements (Minnée, 2008). The ship of reference is a 58.561 dwt deep sea containership with a cargo load of 24436 t., a time in port of 1,5 day and a bunker consumption of 2.133 t per trip. We selected a container vessel as reference, because this type of ship causes a significant part of the emission (Gunner, 2007).

The costs estimators were implemented in spreadsheet calculations to find the entire costs of a trip.

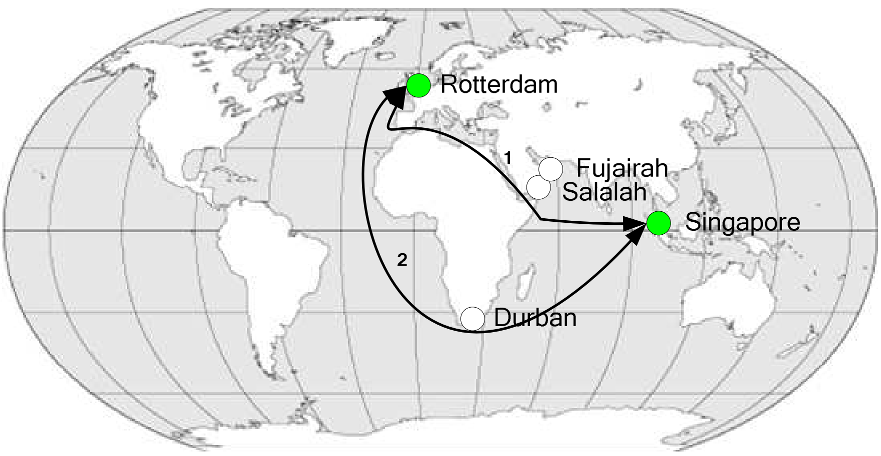

Figure 1. Shipping routes of vessels sailing between Rotterdam and Singapore. The dots indicate ports that could be serious competitors for bunkering.

The results of the model show, not surprisingly, that in the current situation there is no incentive for ship-owners on the Europe-Asia route to call one of the ports in the middle of the route only for bunkering. This offers the opportunity to impose taxes on bunker oil with high sulphur content. This is illustrated in Figure 2. For reasons of confidentiality, results are only qualitative. The tax rate in case of collaboration may be optimized to discourage the use of low quality bunker oil without losing the trade of high quality bunker oil. Collaboration between Singapore and Rotterdam is a prerequisite as round trip bunkering jeopardizes this system.

The analysis above shows, that cooperation between the two major bunker ports on the Europe-Asia route enables the discouragement of the use of low quality bunker without losing market share.

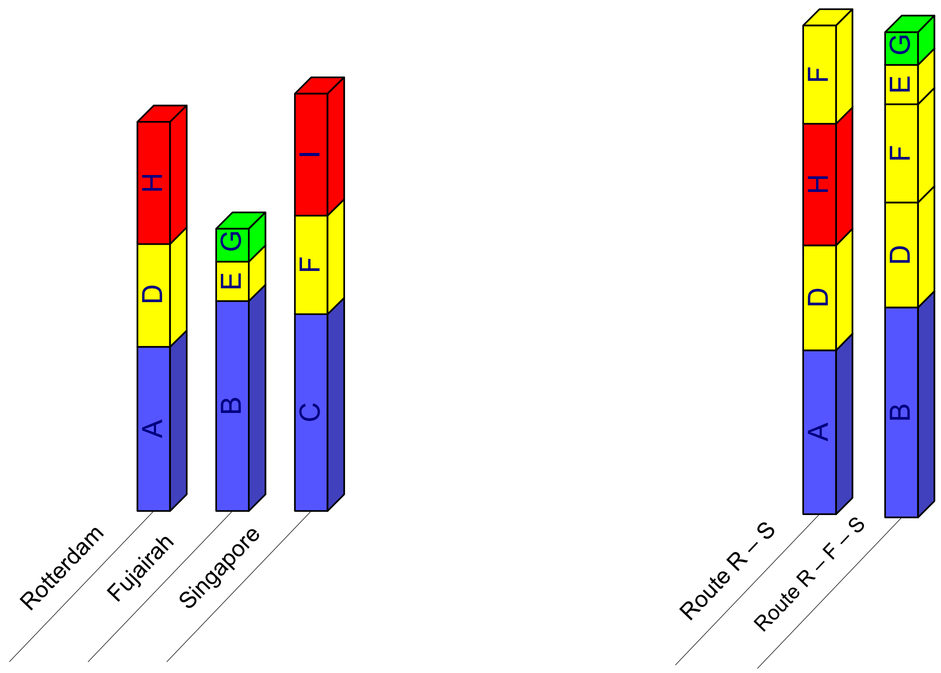

Figure 2. Illustrative maximum costs per port (left) and per shipping route (Right). A, B and C are bunker costs, D, E and F are port dues, G is costs for extra nautical miles of sailing, H, I tax on bunkering

Regulation

We will show that there are several types of regulation. Three of them apply to the Port of Rotterdam. Only one applies to the Port of Singapore. In due time, these regulation will stimulate the ports to take measure for reducing SO_2 emissions.

The current regulations for SO2 emissions are based on the International Convention for the Prevention of Pollution from Ships. This came about in 1973 and was modified by the protocol of 1978 [IMO, 1998]. The EU regulation for this issue is predominantly based on MARPOL Annex VI [EC, 2005]. In addition to MARPOL, the EU directive prescribes that, from 2010, during their stay in a port, ships are permitted to use fuels that have a maximum of 0,1% m/m sulphur. The Netherlands have implemented these EU regulations about the content of sulphur in fuel [Ministerie van Verkeer en Waterstaat, 1983]. At this moment, MARPOL Annex VI states that the sulphur content should not exceed 4,5% by mass and should not exceed 1,5% by mass in SECA (SOx Emission Control Areas) areas. These areas are at this moment the North Sea and the Baltic Sea [IMO, 1998].

The international agreements, made by the International Maritime Organization (IMO) in October 2008 are an encouraging start to reduce the percentages of polluting substances in emissions caused by the use of bunker oil. Stricter regulations are to be expected on the long term. Figure 3 gives the sulfur limits and implementation dates.

The future regulations that were proposed by the IMO have their consequences for all the actors involved in the bunker world. E.g. they can imply changes on board ships to handle three types of fuel, each with their own quality (port, SECA, ocean). In addition, refineries might need to adapt their processes as well. Reducing the sulphur percentage in residual oil is technically possible but needs more processes within refineries than currently needed to meet the norms and standards. At present, the refineries do not have the capacity to do so. This means that the refinery industry needs to make large investments in order to deliver the required quality of the fuels.

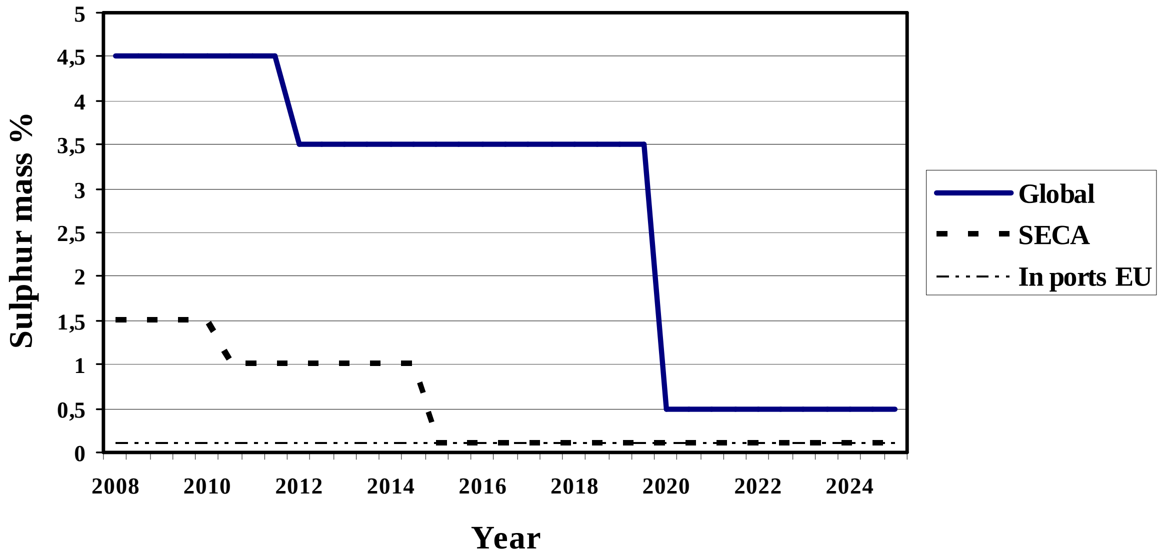

Figure 3. Future Sulfur Limits based on the MARPOL revised Annex VI (Marpol, 2008)

The port of Rotterdam is committed to the three regulations in figure 3. The port of Singapore commits itself to the international regulations, but does not have a SECA area and is not bound to EC-specific regulations.

Options for emission reduction

The chapter "The value of collaboration" revealed a margin for charging emitting shipping companies without losing share in the bunker oil market.

Options for the reduction of emissions can be divided into three different groups (DeMers and Walters, 1999): pre-treatment, primary methods and secondary methods. In the article, we use the classifications preventive, operational and curative options.

Preventive options comprise lowering the sulphur content in bunker oil and using alternative fuel or energy sources. Lowering the sulphur content in residual oils in the refining process is technically possible. However, high investments by refineries are needed for the production of synthetic fuels, fourth generation cracker and advanced processes for desulphurization. Alternative or cleaner fuels, which are already on the fuel market, include marine diesel oil, natural gas and low-sulphur fuels. Other alternative fuels or energy sources, which emit fewer substances, might not yet be commercially available yet. However, they could be an interesting option in the future. Examples of these alternative energy sources can be nuclear energy and solar energy. Wind energy is now already used in limited amounts (SkySails, 2006). Another alternative fuel is shore side electricity. In the port of Rotterdam, a two-year pilot has been started to see if this method is feasible. At this point only inland ships can take part in this pilot. Shore side electricity is an alternative for the use of fuel on board during a stay in a port.

Operational options consist of modifications or optimization of the current system. Internal engine adjustments and engine process modifications can help to lower the emissions. Many of the available adjustments focus on the reduction of NOx emissions, which are determined by engine design and the combustion process itself (Wahlström, Karvosenoja and Porvari, 2006).

Not only the quality of the fuel is important, but also the quantity is relevant for emissions that occur. The amount of fuel that is burned during a voyage depends on multiple factors.

One of these factors is speed. There is a theory that identifies an exponential relation between the speed of a vessel and the usage of fuel. Now, due to high oil prices and a weak market, some container shipping companies are experimenting by slowing down the speed of their vessels, in order to reduce the consumption of fuel.

Table 3. Emission control technologies and their reduction efficiencies (Cofala 2007, Martinek 2000)

Measure	Maximal Reduction of SO_2 emissions [%]
Exhaust gas recirculation	93 %
Fuel switching 2,7 > 0,1% S residual oil fuel	81 %
Low S marine diesel 0,5 > 0,1% S	80 %
Sea water scrubbing	75 %
Fuel switching 2,7 > 1,5% S residual oil fuel	44 %
Improved fleet planning	40 %
Optimised hull shape / maintenance new ship	20 %
Choice of propeller / propeller maintenance new ship	10 %
Optimised hull shape / maintenance existing ship	5 %
“Just in time” routing	5 %
Optimal cargo handling	5 %
Choice of propeller/propeller maintenance existing ship	3 %
Weather routing	2 %
Constant RPM	2 %
Optimal propeller pitch	2 %
Optimal berthing, mooring and anchoring	2 %
Optimal trim	1 %
Minimum ballast	1 %
Optimal rudder	0,3 %

Besides the speed, the route that a ship has to sail is also relevant. A closer look at different routes might help. Varying weather, current and depth conditions during a voyage affect the ship speed. Through routing techniques, fuel savings may be gained. For such optimizations, a reliable weather and current forecast will be needed (MARINTEK, 2000). Although routing has been under serious attention of the shipping companies, changing the order of the ports that are due can lead to a reduction in distance. In addition, there are several canals which provide short-cuts (e.g. Suez and Panama Canal) which put limits on the size of the vessel that can sail on that route. Using smaller vessels could in that case lead to a large reduction of distance that needs to be traveled. These revisions of routes might be more interesting at this point in time due to the rise of the oil price.

There are port related options to reduce fuel use and thus lower SO2 emissions: "Currently, the largest restrictions are related to limitations on ship draught, length and beam, congestion and other limitations on quick port turn-around. Implementation requires infrastructure development. Measures in this category are typically; larger capacity, fewer restrictions on ship draught, beam or length, 24/7 port operation, quicker loading and discharging, more efficient port clearance and slot time allocation" (IMO, Marine Environment Protection Committee, 2008, p. 2).

Since the resistance of the vessel to the water plays a highly important role, a hull shape design for a lower speed could reduce fuel consumption. New developed coating of the vessel could also help to reduce the resistance. On board, newly designed engines could not only help to lower to emissions directly, but could also help to reduce the amount of fuel used. These engines could optimize the combustion of fuel and therefore reduce the use of fuel. Research has indicated that optimal hull maintenance and propeller maintenance can also lead to a reduction of fuel usage (MARINTEK, 2000).

Curative options are applied after the emissions have been formed and are generally called end-of–pipe solutions. They comprise exhaust gas techniques such as scrubbing with sea water or exhaust gas recirculation.

All the possibilities to reduce emissions have their own efficiency. Table 3 indicates some of the measures that can be executed to reduce the SO2 emission.

The analysis above shows that ample options are available for reducing the air pollution due to sea transport.

Options for Policy Measures

There are several options available for reducing the emissions from vessels. Most of these options will not be implemented if the right circumstances are missing. The key driver for entrepreneurs is running an economical attractive business. Policy measures may create the right stimuli for implementing the options. Most of these policies can be categorized in a few types (Ortmanns, 2007).

Once a successful technology is found to reduce emissions and negative side effects are limited, a government or authority can decide to implement measures or regulations that stimulate the use of one or more specific technologies. The problem with this idea is that there are many different stakeholders involved in the issue of reducing emissions, each with its own goals, objectives and interests. While a technology can be considered excellent by one stakeholder, another stakeholder might not like it at all. Therefore, at this point, choosing one technology does not seem likely to succeed.

Port tariffs may be adjusted to the type and amount of emissions a vessel produces. This policy can be made specifically for one pollutant (e.g. CO_2) or could include multiple pollutants (e.g. CO_2, SO_2 and NO_x). A few ports have already implemented this system, or have considered these policies. For instance, in Sweden there are differentiated port dues since 1998 (Ljunggren, 2002). This type of policies will have more influence if the policies are implemented in more ports in order to create a common system.

When implementing distance related emission charges, the charges are based on the distance the ship has traveled before entering the port. E.g. the distance traveled in the North Sea before entering the port of Rotterdam. The profit that is made with the extra charges should be used on environmental issues involving these emissions. The problem with these type of measures is the fact that ships might sail extra nautical miles to reduce the charges. If other ports are not participating in this system, ships might sail to one of these ports first in order to shorten the shipping distance before entering the port with the charges. This leads to extra nautical miles of sailing and therefore it can lead to extra emissions. That is not the intention of the proposed measure. Again, these measures only work when a group of ports cooperates in these policies. E.g. all ports in Europe.

The use of taxation on emissions is another strategy to reduce emissions. Although now replaced by a fund, Norway used to have a tax on NO_x emissions (Rodseth and Arnesen, 2007). This tax was based on a certain amount of Euros per kg NO_x. The collected tax can be used for the financing of other techniques to reduce emissions or possibly the reduction of other environmental issues. These taxes should include all vessels, regardless of the vessel's nationality. If not, there is a possibility that vessels will shift to another flag in order to avoid these taxes. A difficult aspect of using taxation on emissions is the fact that these only reach the national coastal areas. The emissions emitted just outside these areas can still lead to environmental and health problems on land. Furthermore, it is difficult to expand this type of policy internationally. Another way of using taxation is by putting tax on bunkering. A specific tax on Heavy Fuel Oil could lead to a decrease in bunkering of HFO and an increase in bunkering of distillate. This is a cleaner type of fuel, which leads to fewer emissions.

Emission trading is another option to reduce the emissions from vessels. This can be done in different ways. A cap is set for a given year and a given sea area (a total number of emission allowances, each of which provides its owner with the right to emit a unit of emissions). Having this cap, a system of crediting could be developed which would allow vessels to receive reduction credits when emissions are reduced. These credits can be sold at a market. A trading system on voluntary basis gives the opportunity to all ships in a specific region to sell their emission credits (Ortmanns, 2007). In addition, land-based companies could get involved in such a system. The companies could implement emission-reducing techniques on a voluntary base to get more credits.

The analysis above shows that ample policies are available for reducing the air pollution due to sea transport.

Actors

An inventory was made of involved parties in Rotterdam and Singapore (Minnée, 2008). All stakeholders are identified that have significant authorative responsibilities, and all stakeholders are identified that can influence the SO2 issue. With the help of two network maps (see Figure 4 and 5), one for each country, the relations and interdependencies between stakeholders are identified. These maps help to identify interdependencies within a network. In this article we do not describe all these actors.

The first and most noticeable difference between figure 4 and 5 is the number of actors that play an important role. Rotterdam has far more stakeholders that are of importance for a positive result than Singapore has. The use of branch organizations for each type of industry is quite common in the Netherlands, while hardly used in Singapore. The SSA represents almost all types of industry in the port of Singapore.

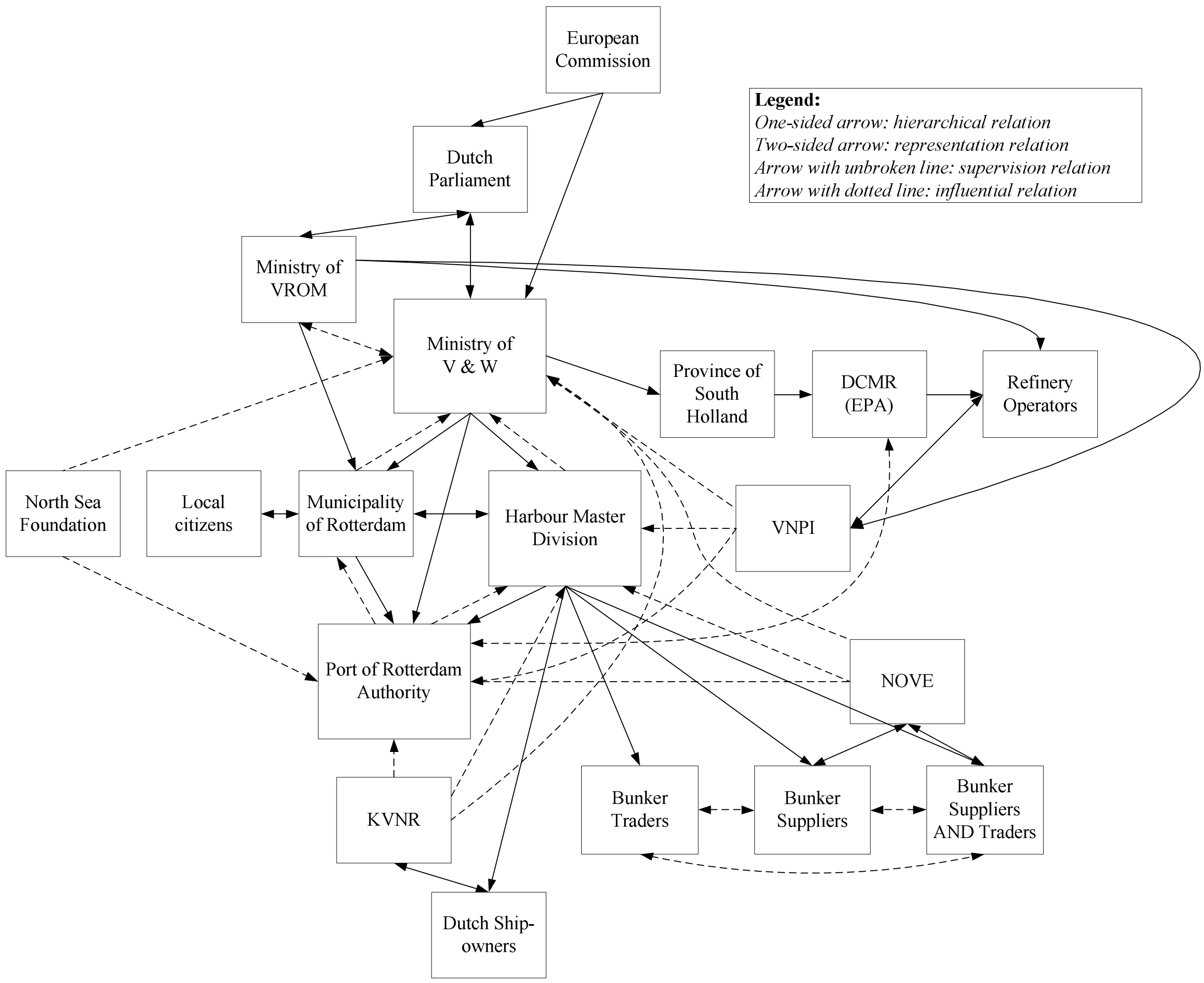

Figure 4. Relations between actors in Rotterdam/Netherlands

The port authority of Rotterdam is a private organization and does not have the authority to implement regulations. In Singapore, the port authority, as a result of their public status, does have some authority to implement new measures and regulations.

An important and very evident cultural difference is the dissimilarity in the way citizens deal with governmental decisions and industrial activities that influence them. The Dutch citizens and companies have a scrupulous attitude and are used to unite in branch organizations and many environmental organizations when decisions are made that do not suit them. In Singapore, it is almost the other way round. Citizens are quite happy with the government and its decisions. Trust and faith in what the government decides is very high (Alam K., 2008). Singapore does not have an independent environmental organization.

Singapore is a state with an overall policy that is focused primarily on the economy, but not at cost of the environment. In the Netherlands and Europe, the environmental issues are high on the political agenda, but not at all costs.

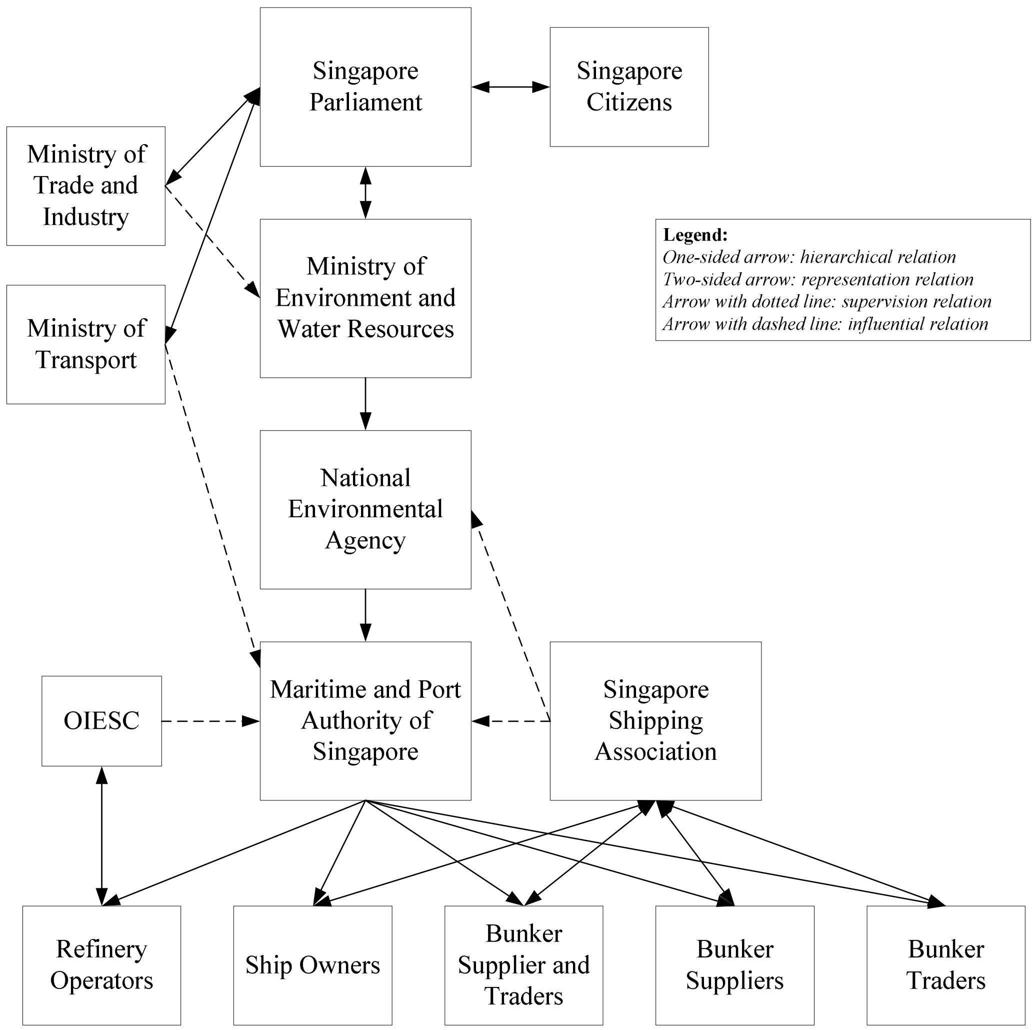

Figure 5. Relations between actors in Singapore

Conclusions

We conclude that regulatory and economical drivers, technical, operational and policy options are sufficiently available to justify a collaboration between the Port of Rotterdam and the Port of Singapore to obtain joint reduction of bunker oil related emissions. However, the approach to start the collaboration is a major issue, due to differences in culture and organization.

For the port authorities of Rotterdam and Singapore, as well as for the shipping companies and refineries, the long-term driver for taking measures to reduce emissions due to bunker is the revised annex VI Fuel Sulfur Limits, which was adopted on 10 October 2008. As both ports highly depend on crude oil refining and bunker oil trade a proactive strategy is essential. With a spreadsheet model for bunkering costs of the Europe-Asia route, we revealed a second driver. Cooperation between the port of Rotterdam and Singapore, instead of competition, results in a costs gap and thus offers opportunities for financial discouragement of the use of low quality bunker, without losing market share.

Ample options are available for reducing the air pollution due to sea transport and abundant policies are available for reducing the air pollution due to sea transport. However, both port authorities do not have the power to enforce policies or options for reduction of SO_2 emissions. They have to create a group of dedicated and critical actors to implement these policies or options. The actor analysis demonstrates the difference in the social structures in Singapore and Rotterdam for creating commitment.

The decentralized distribution of authorities, the amount of branch organizations, the amount of environmental organizations and the space for an opinionated public all lead to the conclusion that the organizational structure within the Netherlands is best described as a network. Singapore on the other hand has an organizational structure that is best described by a hierarchy: the authority is centralized and there are not so many other stakeholders that have authority of resources to influence the decision-making.

Cooperation between the port authorities of Singapore and Rotterdam will result in a rich pallet of options and policies and will have extra benefits as compared to a situation without cooperation. The different management styles and different social structures urge for a delicate process design for collaboration.

In this research, we focused on a specific topic. From a higher-level point of view, we see that Environmental issues worldwide are growing in importance. All parties involved are paying more attention. However, suggestions, arguments and pro and contra measures and regulations are still a long way of finding the correct equilibrium. Time on one end and wisdom on the other will eventually find the right solutions.

This paper indicates the necessity for further research and suggests one method that may result in impact on a limited amount of players but will undoubtedly also spark reactions that may help to find the correct answer.

List of Abbreviations

EC	European Commission
EPA / DCMR	Environmental Protection Agency Rijnmond
EU	European Union
HFO	Heavy Fuel Oil
IMO	International Maritime Organisation
KVNR	Royal Association of Dutch ship-owners
MARPOL 73/78	International Convention for the Prevention of Pollution From Ships
Ministry of V&W	Ministry of Transport, Water Management and Public Works
Ministry of VROM	Ministry of Public Health, Spatial Planning and Environment
MPA	Maritime and Port Authority of Singapore
NEA	National Environmental Agency (Singapore)
NOVE	(Dutch branch organisation for independent bunker companies)
OIESC	Oil Industry Environment Steering Committee
PM	Particulate Matter
PoR	Port of Rotterdam Authority
SECA	Sulphur Emission control Areas

SRC	Singapore Refining Company Private Limited
SSA	Singapore Shipping Association
VNPI	Vereniging Nederlandse Petroleum Industrie

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